Research on Object-Oriented Geographical Data Model in GIS

Wang Qingshan, Wang Jiayao, Zhou Haiyan, Li Bin

Institute of Information Engineering University
66 Longhai Road, ZhengZhou 450052, P.R.China

Abstract Nowadays, there are many attempts to establish object-oriented GIS in some software However, they are not accordant to object-oriented concept whole and systematically in the whole course from the process of cognizing and abstracting geographical space to the process of defining and describing GIS data model then to the process of analyzing and designing GIS. Especially, the research on common object-oriented geographical data model is infrequent. In light of this case, based on geographic spatial cognition to the real world, this paper puts forward a common Object-oriented Geographic Data Model (OGDM) by using object-oriented methods and provides a model for establishing the implemental GIS.

Keywords Object-oriented, Geometry Object Model, Geographical Feature Object Model, Graphical Description Object Model

Introduce

In the real world, people always cognize things, phenomena and their relations in some definite fields. That is to say, the domain of research is determined at the beginning. Then objects to be studied are ascertained. Finally relations of all objects are formed. The domain of OGDM is the geographical space in the real world. The geographical space can be the globe, one country, or one region. The geographical space within a determinate scope is defined as a workspace. The geographical space may consist of several workspaces, which can be overlapped each other. The workspace is a window through which we can recognize and operate geographical spatial entities and their relations described by GIS. In a workspace, each kind of geographical entity and phenomenon is named as a geographical feature (or object). The aggregate of all correlative geographical features in the determinate spatial territory is named as geographical feature layer. Geographical feature includes spatial data, attribute data and temporal data. Spatial data includes position data and spatial relations. The data structure of model describes not only position data, but also topology-relations of objects. Attribute data and temporal data represent quality, types, state, period, duration, and so on and they are described by the structure element of attribute data.

Every material geographic space may have a hierarchic and classified architecture. For example, geographical space can be divided into communication, water system, district, residence, terrain, etc. Moreover, communication includes road, railway, etc. and water system includes river, reservoir, lakes, etc. According to the hierarchic architecture of geographic space, we can abstract the frame of OGDM in figure 1 as follows.

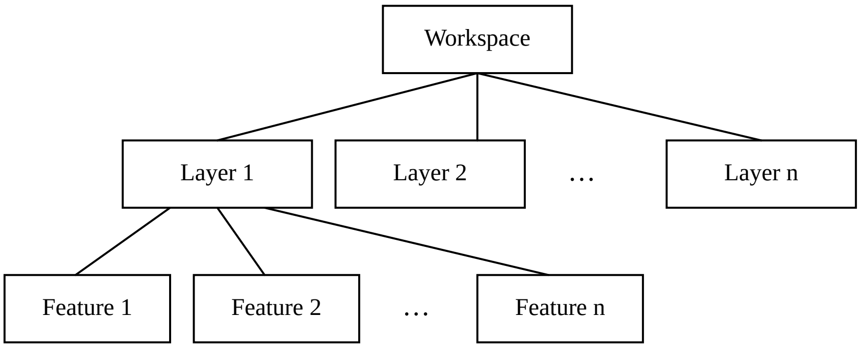


Figure 1 the frame of OGDM

1. Workspace

A continuous geographical space within a determinate scope is defined as a workspace, which concludes several geographical feature layers. The main purpose of workspace is to manage geographic spatial data well and effectively, and by utilizing geographical feature layer to organize geographical features scientifically, and to store geographical features logically, and to query geographical feature effectively, then to serve higher level of spatial analysis and decision-making. Workspace mainly includes the metadata of GIS database such as description of geographical spatial data, data source, produced time, projection, quality, precision, resolution, scale, etc.

2. Layer

Layer is defined as an aggregate of all correlative geographical features (or objects) in the determinate spatial territory. When we comprehend and analysis geographical entities or phenomena, classification is always necessary, which collects all correlative features in the determinate spatial territory. For instance, geographical space is classified into several classes of geographical feature such as communication, water system, residence and terrain. Each geographical feature class is corresponding to a layer. Of course, the layer is not classified only in this method but in other methods according to user's like. For example, user can classify highway and ordinary road into different layers. Each layer is relatively independent in organization and structure. A layer is the basal unit for applications such as update, query, analysis and display. Besides storing and managing a certain kind of geographical feature, sometimes, it establishes topology-relations in order to maintain the coherence and integrality of topology on some kind type of geographical layers.

3. Feature

Feature is the basal expression of geographical entities and phenomena (USGS，Guptill，1990；Tang，1996). A feature includes two-sides meanings. In concept world it represents geographical entity of the real world, but in data world it represents geographical object. It includes spatial character, attribute character and temporal character. The content of feature is described in figure 2 as follows.

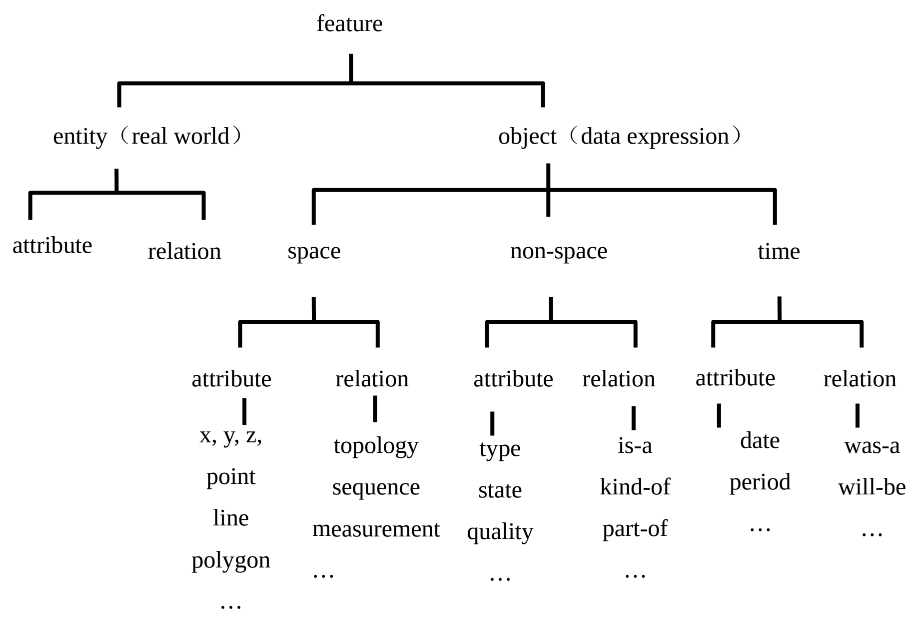


Figure 2 the content of Feature

Spatial characters of feature include spatial attributes and spatial relations. Spatial attributes are serial coordinates, which represent the spatial position of a feature. The spatial position includes coordinates including X, Y, Z, point, line, area, surface, body, pixel, and so on. Spatial relations include topological relations and non-topological relations (sequence, measurement etc.) Non-spatial characters of feature include non-spatial attributes and non-spatial relations. Non-spatial attribute represents feature's attribute information such as type, number, quality, state and so on. Non-spatial relations represent relations of features such as is-a, is-a-kind-of, is-a-part-of, is-above, and so on. Temporal characters of feature include temporal attributes and temporal relations. Temporal attributes represent the produced time and duration of data. Temporal relations represent data of was-a, will-be, and so on.

In OGDM, features and their relations sketch attribute relations and composing relations of geographical entities. However, Geometry objects and their relations describe spatial position, spatial distribution and spatial relation of geographical entities. Therefore, OGDM includes two connotative hierarchic object-models, namely Geometry Object Model and Geographical Feature Object Model.

Geometry Object Model

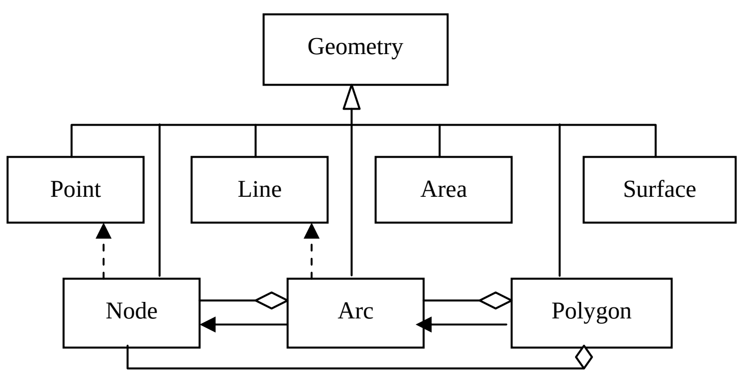
Geometry Object Model researches on geographical space on the view of pure geometry. It abstracts geographical space as an aggregate of geographical objects. These objects not only describe information of features such as shape, position, distribution, spatial relation (non-topology relation and topology relation), but also encapsulate methods which operator those information. Geometry Object includes four elementary types, namely point, line, area and surface in vector data structure. If topology-relations of geometry objects in geographical space are taken into account, Geometry Objects in vector data structure can be classified into three topology types: node, arc, polygon.

At present, there are two methods for establishing topology of geometry objects. One stores topological relation in the data structure used by some GIS software such as ARC/INFO, MGE, GENAMAP and some scholars like Agatha Y. Tang. The other does not stores topology relation in the data structure in some GIS software such as MapInfo, ArcView, SDE, SDO and in the simple element criterion of OpenGIS, in which the spatial relation is calculated by mathematic methods (Such as DE9-IM).

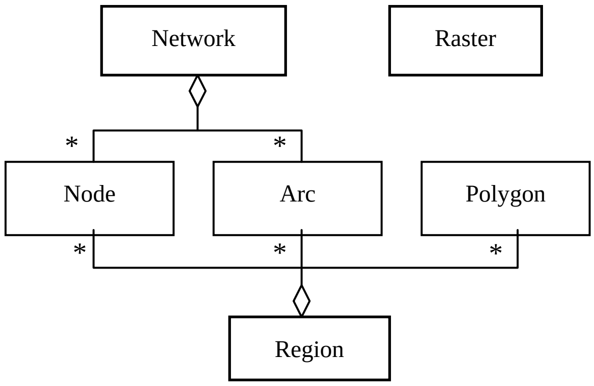
The most typical and influential topology data structure is POLYVRT (Polygon Convertor) researched by America Institute of Computer Graphics and Spatial Analysis Research. Arc is the basis of the data structure. An arc has two nodes on its ends and is composed of faculative midpoints, with a mark of left polygon and a mark of right polygon and both sharing the arc. Topology data structure does not store communal arcs of polygon repetitively. Therefore, it can save many storage units. Topology-relation is stored in the data structure, which is advantageous to query operations such as adjoining, containing and jointing, and which can accelerate spatial analysis. However, due to the complexity of the data structure and relations of geometry objects, topology-relations will be destroyed after editor operations such as adding, deleting and modifying. Topology-relations must be re-established by topology arithmetic to maintain the coherence and integrality of topological relations. At the same time, the speed of display is slow and graphics are displayed factitiously.

In non-topology relation data structure, the structure is simple. Graphics are displayed quickly. Coordinates are directly corresponding to Geometry Objects so that data may be edited easily. After editor, other disposals are not necessary. Spatial relations of Geometry Objects can be calculated by mathematic methods such as the Dimensionally Extended Nine-Intersection Model (DE9-IM). However, because communal arcs of polygon are stored repetitively, there are many redundant data.

In fact, any system which stores topology relations data needs to obtain data of non-topology geometry object firstly, then convert them to topology structure data, through either man-made topology disposal means or automatic topology disposal means. We can unify these two structures. When data are collected, edited, speediness-displayed, elementary geometry objects such as point, line and area are mainly operated. When we carry through some spatial analysis such as net-analysis, path-analysis, overlapping-analysis, point and line will be converted to node and arc, then the type of net and the type of net polygon form are formed. Using net and polygon, we can carry through spatial analysis. Geometry Object Model of OGDM is represented in figure 3 as follows.



a. Basic Geometrical Object



b. Complex Geometrical Object

Figure 3 Geometry Object Model of OGDM

Geographical Feature Object Model

Because many GIS applications need spatial feature to query orientation, relations and geographical meanings of features, Geometry Object Model ignores inherent geographical meanings of features in order to keep Geometry object's independence in operation and query. In the process of visualizing, features are always displayed as geometric graphics. In addition, one geometry object may be corresponding to several different features. Thus, it is necessary to establish Geometry Object Model independently in order to implement certain applications. But in some higher level of applications, users mainly query, index and analyze features and their relations (including spatial relations, attribute component relations and hierarchic relations, etc). Therefore, it becomes an important content of geometric data model to establish Geometry Feature Object Model, which includes spatial attribute, non-spatial attribute and making features as operation object and interface surface.

1 Elementary Geographical Feature Object Model

Compared with Geometry Object Model, Geographical Feature Object Model defines and explains Geometry object wholly. It also puts attribute to geometry object. A geographical feature object consists of a Geometry object and the attribute (or semantics) to describe it. In a feature class, Geometry Object is the main part of geographical feature object. Features are classified by Geometry Objects. On the base of Geometry Object Model, features can be divided into seven elementary types: point, line, area, surface, node, arc and polygon. They are corresponding to the objects of Geometry Object Model one-to-one and are added attribute information on the base of Geometry object. The attribute's hierarchic relation and feature's composing relation of Geometry Objects are determined by attribute data. The other spatial relations are determined by Geometry object. All spatial operations of Geometry objects are acted on geographical feature objects. Therefore, Geometry feature inherit from Geometry object so that spatial structure, spatial relation and spatial operation inherit from Geometry object class that is a super class.

2 Graphical Feature Set Object Model

Many GIS applications need to manage and display geographical feature objects by a passel or a group. Results of applications such as querying, selecting and analyzing are expressed by means of feature sets. In addition, the spatial overlapping-analysis must be operated between feature sets. Therefore, it is necessary to establish geographical feature set object classes which aggregate or associate elementary geographical feature objects.

Graphical Description Object Model

It is an important function to visualize geographical data in GIS other than store, manage, query and operate them efficiently so that user can cognize geographic spatial entities or phenomena and their relations from graphics. The visualization of the geographical data is one of main functions of GIS.

In course of establishing data model, the visualization of the geographical data must take account of these factors which are basic issues of the visualization of geographical data as follows:

(1) Graphics of features such as point, line, area (including node, arc and polygon)

(2) Annotation of geographical feature

（3） Statistic thematic map

Holistic OGDM

Geometry Object Model, Geometry Feature Object Model and Graphical Description Object Model describe complicated geographical entities, phenomena and their relations synthetically. The hierarchical management of geographical feature objects by using the conception of workspace and layer not only accords with the natural hierarchical structure of geographical space, but also confines in a suitable scope so that user can choose different types of geographical feature layer conveniently and flexibly to organize and manage data.

Workspace is the main view of GIS, which is a part of the geographical space user studies. It can be abstracted as a geographical object set which distribute in the two-dimension space. There are homogeneous relation, spatial relation and composing relation among geographical features. Homogeneous features have a group of attributes that have the same character to describe their features qualitatively and quantitatively. For example, the river class may have attributes such as length, flux, level and average velocity of flow. The spatial relation emphasizes topology-relation, sequence-relation and measurement-relation among features and the relation calculated by spatial analysis arithmetic. The composing relation emphasizes the aggregation relation and the association relation among features. In workspace, features are gathered by some definite principles of classify and form different geographical layers. Generally, a geographical layer includes a group of geographical features in a determinate scope and is organized by the geographical feature set class abstracted in the model. In OGDM, there are six types of geographical layers: point, line, area, surface, net and polygon. They are represented and organized by classes of geographical feature sets. Each class is corresponding to a geographical layer. Net feature layer includes node and arc and maintains their topology relations. Polygon feature layer includes node, arc and polygon and maintains their topology relations either. The holistic OGDM is represented in Figure 4 as follows.

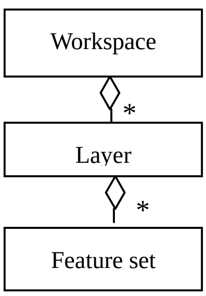


Figure 4 Holistic OGDM

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